PREDATION BY FISH ON WALLEYE EGGS ON A SPAWNING REEF IN WESTERN LAKE ERIE, 1969–71[1, 2]

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Nearly 2,000 fish representing 21 species were captured with experimental gillnets on Kelleys Island Shoal during the spawning and incubation periods of walleyes (*Stizostedion v. vitreum*) in 1969–71. A total of 794 stomachs were examined. Four species contained walleye eggs: yellow perch (*Perca flavescens*), spottail shiner (*Notropis hudsonius*), stonecat (*Noturus flavus*) and white sucker (*Catostomus commersoni*). Yellow perch were by far the most consistent predators of walleye eggs, and spent female perch consumed more eggs than did males. The average number of walleye eggs in perch stomachs collected on any one day ranged from 36 to 734 for females and from 4 to 237 for males. The loss of walleye eggs due to fish predation appeared to be significant only when the rate of water warming slowed or stopped, thereby creating an extended overlap in the walleye–yellow perch reproductive period. Only under the uncommon condition of an extended time interval between walleye hatching and perch spawning, coupled with the presence of a large quantity of actively feeding perch, could egg predation reduce walleye reproductive success.

The walleye population of western Lake Erie has shown two disturbing signs of heavy stress over the past 15 years. First, annual commercial production of walleyes in Lake Erie, which rose from 2.1 million pounds (954 thousand kg) in 1935 to nearly 15.4 million pounds (7 million kg) in 1956 before the fishery collapsed in the late 1950's, dropped to 0.7 million pounds (318 thousand kg) by 1962 and never again exceeded 1 million pounds (454 thousand kg). The fishery was closed in western Lake Erie in 1970 when the average level of mercury in adult walleyes exceeded the "safe" guideline of 0.5 ppm established by the U.S. Food and Drug Administration. The second disturbing sign has been the great instability in recruitment since the mid-1950's. Large annual hatches were generally the rule before 1955, but since then the only exceptions to small year classes have been the fair ones of 1959 and 1965 and the relatively strong ones of 1962 and 1970 (Van Meter and Hartman 1974).

Beginning in the early 1960's, efforts were intensified to determine what factors affected the erratic year-class success of walleyes in western Lake Erie. Walleye egg predation by fish was once believed to be a serious problem in some lakes (Bean 1912; Goode 1903; Surber 1925). The present study was conducted to determine if predation on walleye eggs by fish was a factor that significantly affected year-class strength in western Lake Erie. Fish were collected with gillnets from Kelleys Island Shoal, a known walleye spawning reef, during the spawning and incubation periods in 1969–71.

STUDY AREA

Kelleys Island Shoal is about 1,500 m northeast of Kelleys Island in the western basin of Lake Erie (fig. 1). The shoal is a kidney-shaped bedrock outcropping about 2,600 m long and 600 m wide at the 5m contour (Herdendorf and Braidech 1970). An area of about 80 ha is shallower than 5 m, and most of the shallowest part is less than 1 m below the lake surface. The reef is covered with rubble ranging in size from small pebbles to boulders more than 1 m in diameter. Although a few millimeters of silt periodically accumulate in depressions of the bedrock, wave action washing the reef surface keeps it generally clean (Herdendorf and Braidech 1970). The water adjacent to the reef is 9 to 12 m deep, and the bottom there is silty mud.

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MATERIALS AND METHODS

Nylon gillnets were fished on the lake bottom during the walleye spawning and incubation periods in 1969–71 at Kelleys Island Shoal. Each net consisted of one 100 x 6 ft (30 x 1.8 m) panel each of five mesh sizes: 2.0, 2.5, 3.0, 3.5, and 4.0 inches (5.1, 6.4, 7.6, 8.9, 10.2 cm) (stretched measure). In addition, a 50 x 6 ft (15 x 1.8 m) panel of 1.5 inch (3.8 cm) mesh was fished in 1969; the length of this net was reduced to 25 ft (7.6 m) for most of the 1970 collection period and all of the 1971 period because of the large number of smelt captured with it in the first two lifts during the 1970 sampling period. Nets were set east of the 1 m contour on the reef, at depths of 1.5 to 3.5 m (fig. 1). Each

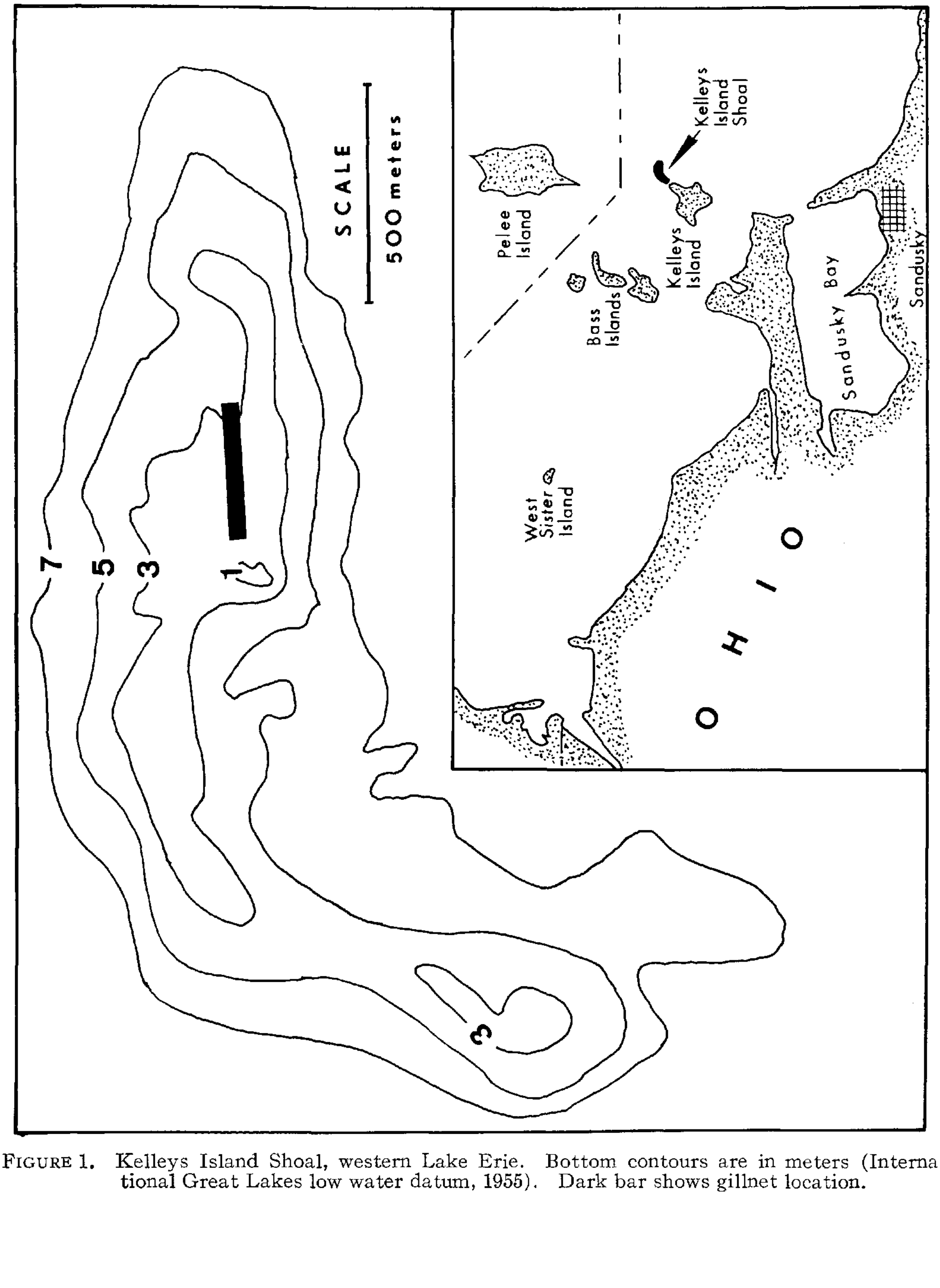

FIGURE 1. Kelleys Island Shoal, western Lake Erie. Bottom contours are in meters (International Great Lakes low water datum, 1955). Dark bar shows gillnet location.

net was usually set by early afternoon and lifted the following morning. Five sets were made in 1969, 7 in 1970, and 10 in 1971. Stomachs of all fish in small catches were preserved for later examination; large catches were usually subsampled. Either the digestive tract or the entire specimen was preserved in 10% formalin. No allowance was made for possible regurgitation of stomach contents or periodicity of feeding by the various species. Length, sex, stage of maturity, and age were determined.

Temperatures were monitored on the spawning reef with a constant recording thermograph, installed soon after the spring ice break-up. The thermocouple was positioned about 17.5 cm above the bottom, in water 3 to 4 m deep. Temperatures recorded on the tapes were read to the nearest 0.1 °C at 6 hour intervals.

The relative abundance of walleye eggs was determined by collecting eggs from the reef with the pumping device described by Manz (1964). A steel, sled-type suction head attached by a 3-inch (7.6 cm) hose was dragged along the bottom at about 4.8 km per hour. Water and eggs were sucked up the hose from the bottom and collected on a screen filter. The density of walleye eggs was estimated by counting the number of eggs collected per 10-minute tow of this device.

SPAWNING AND HATCHING

The walleye spawning period varied with the year. Walleyes spawned earlier on Kelleys Island Shoal in 1969 than in 1970 or 1971 because the water warmed earlier (fig. 2). Walleye spawning in western Lake Erie usually begins when water temperature rises to about 4° C (U.S. F.W.S. unpublished data). Water temperature on the reef on April 7 was 4.4° in 1969, compared with 1.7° in 1970 and 1.8° in 1971. The rate of water temperature increase in 1969 and 1970 was steady and comparatively rapid throughout the incubation period with a few slight temperature declines. However, after an initial warming trend in 1971, the water temperature remained

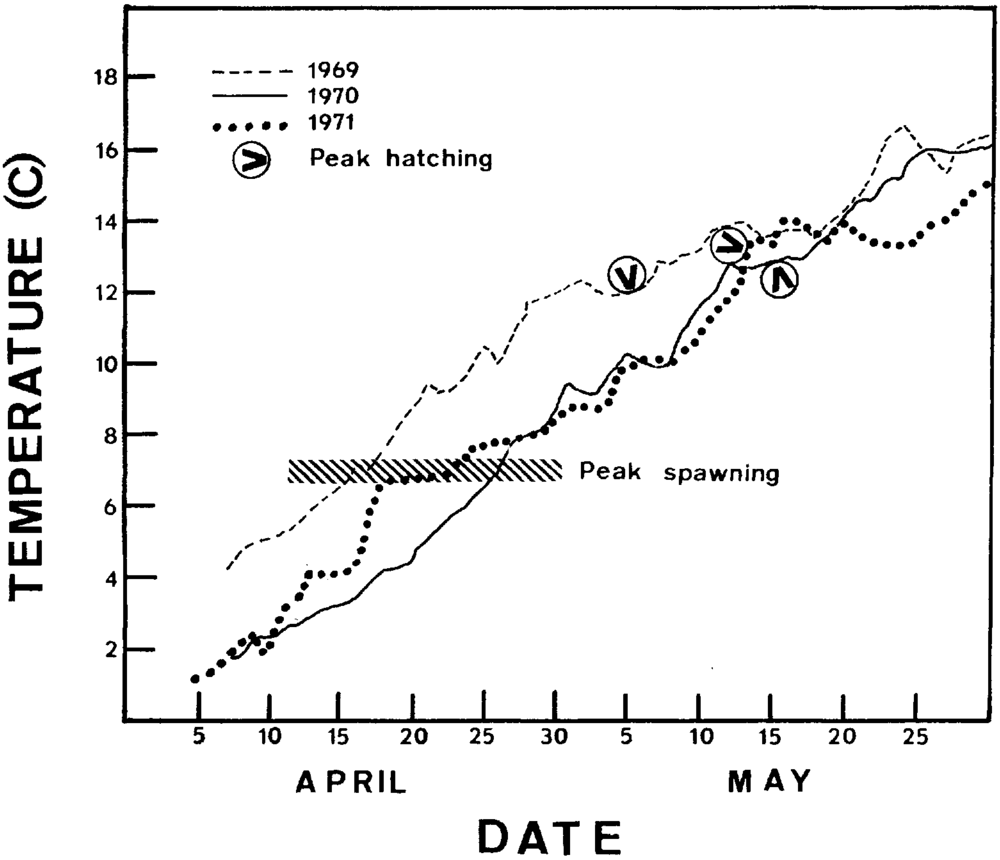

FIGURE 2. Mean daily water temperatures and dates of peak spawning and hatching of walleyes on Kelleys Island Shoal during April and May, 1969–71.

nearly stable from April 18 to 23, after which it rose moderately and gradually during the rest of the incubation period.

The approximate dates of peak walleye hatching for each of the three years were determined by applying the regression described by Hartman (1973) of rate of embryonic development of walleyes on water temperatures:

$$Y = -5.481 + 1.062X$$

where Y = average percentage of development per day towards hatching and X = mean daily incubation temperature in °C. This regression allows determination of the approximate date of peak hatching, given the date of peak spawning and the mean daily post-spawning water temperatures. Peak spawning in Lake Erie occurs at a water temperature of about 7°C (U.S.F.W.S. unpublished data). We calculated the daily rate of egg development for each of the three years, with Hartman's regression and the water temperature data collected in 1969–71. The approximate dates of

TABLE 1

Dates of capture, numbers of stomachs examined, and the major fish species taken in experimental gillnets on Kelleys Island Shoal during the walleye spawning and incubation period.

Date	Yellow perch (*Perca flavescens*)	Walleye (*Stizostedion v. vitreum*)	Spottail shiner (*Notropis hudsonius*)	Rainbow smelt (*Osmerus mordax*)	Stonecat (*Noturus flavus*)	White sucker (*Catostomus commersoni*)	Freshwater drum (*Aplodinotus grunniens*)	White bass (*Morone chrysops*)	Other species
1969									
May 2	200	0	1	0	0	1	1	0	2
May 8	13	7	4	3	0	3	0	0	1
May 15	42	2	43	0	4	1	2	0	0
May 21	8	0	3	0	1	0	0	0	0
June 3	19	1	0	0	1	0	0	0	1
Total	282	10	51	3	6	5	3	0	4
1970									
April 17	0	6	0	52	0	0	0	0	0
April 23	0	11	0	824*	0	0	0	0	1
April 28	1	10	0	2	1	2	0	3	6
May 1	13	11	0	0	1	1	1	3	9
May 8	7	12	0	1	6	0	0	0	2
May 19	10	8	4	1	4	5	4	9	6
May 28	26	2	0	0	2	1	0	7	2
Total	57	60	4	880	14	9	5	22	26
1971									
March 31	0	0	0	48	0	0	0	0	1
April 8	0	1	1	53	0	0	0	0	5
April 15	0	3	0	11	0	1	0	0	1
April 21	0	9	0	178	0	1	0	0	0
April 28	5	3	1	61	0	0	0	2	1
May 5	0	2	0	7	0	0	2	0	1
May 8	9	3	2	3	2	2	1	1	0
May 11	1	11	4	0	0	15	12	1	8
May 14	1	0	0	0	3	1	5	1	0
May 18	1	8	3	1	4	1	35	5	3
Total	17	40	11	362	9	21	55	10	20
Grand total	356	110	66	1,245	29	35	63	32	51
Number of stomachs examined	213	108	65	216	28	30	54	32	48

*Small-mesh (1.5-inch) panel of gillnet reduced from 50 ft to 25 ft after April 23, 1970.

peak hatching were estimated as May 5, 1969, May 15, 1970, and May 14, 1971 (fig. 2). The average length of the incubation period was 19 days in both 1969 and 1970 and 26 days in 1971.

SUCCESSION OF FISH SPECIES ON THE SPAWNING REEF

The relative abundance of various fish species on the reef during the walleye spawning period varied from year to year (table 1). Some fluctuations can be explained by differences in the date of sampling and fishing effort. In 1970 and 1971, gillnetting was started at least 10 days before peak walleye spawning, while in 1969 gillnetting was not started until May 2 with peak spawning around April 17 (table 1; fig. 2). Only 3 rainbow smelt were caught in 1969, and the smelt spawning season was nearly over before the first gillnet was set. More smelt were taken in 1970 than 1971 because more small-mesh netting was fished during part of the 1970 spawning season. One unexplained fluctuation was the large number of yellow perch caught in 1969. Even though fewer nets were fished later in the 1969 season, far more yellow perch were caught (282) than in 1970 (58) or 1971 (17).

General succession of fish species on the reef during the walleye spawning and incubation period occurred in the following order: smelt, walleye, yellow perch, spottail shiner, and freshwater drum (table 1). Smelt, the first species to spawn, apparently moved off the reef after they completed spawning. They were closely followed by male walleyes, which lingered on the reef during the spawning season. Yellow perch, which spawned in other areas, moved onto the reef as the water temperatures increased. The length of time that each species was present on the reef normally overlaps and this overlap increases whenever the increase in water temperature during the spring slows or ceases. Species such as white bass, stonecat, and white sucker appeared to be more abundant during the latter half of the walleye egg incubation period. Numbers of other species that were taken throughout the sampling periods include: *Ictalurus punctatus*—20, *Moxostoma macrolepidotum*—7, *Cyprinus carpio*—5, *Micropterus dolomieui*—5, Carp × goldfish hybrid—3, *Dorosoma cepedianum*—2, *Percopsis omiscomaycus*—2, *Alosa pseudoharengus*—1, *Oncorhynchus kisutch*—1, *Oncorhynchus tshawytscha*—1, *Crassius auratus*—1, *Lota lota*—1, *Ambloplites rupestris*—1, *Lepomis gibbosus*—1.

WALLEYE EGG PREDATION

Of 1,987 fish caught, 794 stomachs were examined (table 1). The stomachs of yellow perch, spottail shiners, stonecat, and white suckers contained walleye eggs (table 2). In 1969, yellow perch were the most abundant fish on the reef (table 1) and items most commonly found in their stomachs were walleye eggs (65%), *Gammarus* (71%), smelt eggs (19%), fish (20%), and snails (17%). Most spottail shiners, also fairly abundant in 1969, had empty stomachs. Chironomid larvae were present in 88% of the spottail shiner stomachs with food, and walleye eggs and *Gammarus* in 13%. One stonecat and one white sucker also had consumed walleye eggs (table 2).

In 1970, perch fed on nearly the same items as in 1969. Frequency of occurrence was 92% for walleye eggs, 71% for *Gammarus*, and 33% for *Physa*. No walleye eggs were found in the other three species that had consumed walleye eggs in 1969. In 1971, both yellow perch and spottail shiners had consumed walleye eggs, but the frequency of occurrence was only 6% and 11%, respectively (table 2).

Predation of walleye eggs by yellow perch usually increased as the perch spawing season progressed and numbers of spent perch increased (table 3). This increase was probably caused by the increased feeding of spent fish. This trait seems to be more characteristic of female than male perch, possibly because females complete spawning in one act. Spawning by males tends to be protracted. For example, in 1969 the percentage of females that were spent in each day's catch increased from 50% on May 2 to 100% on May 15 and May 21. The percentage of perch stomachs containing walleye eggs correspondingly increased from 17% to 100%. The absence of walleye eggs in perch stomachs

TABLE 2
*Food of four species of fish that consumed walleye eggs.**

Item	May 2–June 3, 1969				April 28–May 28, 1970				March 31–May 18, 1971			
	Yellow perch	Spottail shiner	Stonecat	White sucker	Yellow perch	Spottail shiner	Stonecat	White sucker	Yellow perch	Spottail shiner	Stonecat	White sucker
Walleye eggs	65.1	12.5	20.0	25.0	91.7	—	—	—	5.9	11.1	—	—
Smelt eggs	18.6	—	—	—	16.7	—	—	—	5.9	—	—	—
Unidentified eggs	4.7	—	—	—	5.6	—	—	—	—	—	—	6.2
Gammarus	70.9	12.5	60.0	25.0	36.1	—	14.3	11.1	11.8	—	33.3	25.0
Diaptomus	1.2	—	—	—	—	—	—	—	5.9	—	—	6.2
Asellus	—	—	—	—	—	—	—	—	11.8	—	—	—
Chironomid larvae	3.5	87.5	—	—	11.1	—	—	—	—	—	33.3	6.2
Snail (*Physa*)	17.4	—	—	—	33.3	—	—	—	—	22.2	—	—
Snail (*Lymnaea*)	—	—	—	—	2.8	—	—	—	—	11.1	33.3	—
Fish remains	19.8	—	60.0	—	13.9	—	71.4	—	11.8	—	66.7	—
Crayfish	10.5	—	40.0	—	8.3	—	28.6	—	—	—	—	—
Leeches	1.2	—	—	—	—	—	—	—	—	—	—	—
Detritus	—	—	—	50.0	—	—	—	100.0	—	22.2	—	43.8
No. of stomachs with food	86	8	5	4	36	0	7	9	17	5	3	13
No. of stomachs empty	53	43	1	1	21	4	7	0	10	5	5	3

*Data expressed as percentage of stomachs containing food item; based only on stomachs containing food.

TABLE 3
*Percentages of female and male yellow perch containing walleye eggs and percentages spent on different dates.**

Date	Number females	Percent spent	Percent with walleye eggs	Number of eggs		Number males	Percent spent	Percent with walleye eggs	Number of eggs	
				Range	Average				Range	Average
1969										
May 2	18	50.0	16.7	1–1,246	636	52	0.0	0.0	—	—
May 8	12	91.7	83.3	4–1,649	734	1	0.0	0.0	—	—
May 15	40	100.0	95.0	6–1,326	159	2	100.0	100.0	27–447	237
May 21	3	100.0	100.0	4–92	46	0	—	—	—	—
June 3	9	100.0	0.0	—	0	2	100.0	0.0	—	0
1970										
April 28	0	—	—	—	—	1	0.0	100.0	4	4
May 1	3	66.7	33.3	327	327	10	10.0	0.0	—	—
May 8	0	—	—	—	—	7	42.9	0.0	—	—
May 19	7	100.0	85.7	11–86	37	3	100.0	100.0	52–127	79
May 28	11	100.0	81.8	6–64	36	15	100.0	86.7	1–56	20

*Data from 1971 are omitted because only one perch was found with walleye eggs in its stomach.

collected on June 3 was probably due to the absence of eggs on the reef because hatching was completed.

Since the degree of predation increased as the number of spent yellow perch increased and water temperatures greatly influence the time of spawning, we examined the relationship between water temperature and egg predation. Peak spawning of yellow perch in Lake Erie usually occurs when the water temperature reaches 11°–12° C(U.S. F.W.S. unpublished data). Yellow perch normally do not spawn over the same sites as walleyes in western Lake Erie, but prefer near-shore waters over sand or mud bottoms. with rooted aquatic plants. When water temperatures rise slowly, the period of embryonic development of walleye eggs is extended, as is the period when spent yellow perch move onto walleye spawning reefs and consume incubating walleye eggs. The longer the time span between completion of perch spawning and hatching of walleye eggs, the greater the chance for predation. In 1969, a temperature reversal slowed the walleye embryonic development and resulted in an 8-day overlap between peak perch spawning (April 27) and peak walleye hatching (May 5) (fig. 2). In 1970, overlap between peak yellow perch spawning (May 10) and peak walleye hatching (May 16) was 6 days. Even though the percentage frequency for walleye eggs in perch stomachs was high (91.7) in the 1970 collections, few perch were caught (fig. 3). In 1971 the time between peak walleye hatching (May 13) and yellow perch spawning (May 10) was only 3 days and walleye eggs were present in only one of the 27 perch caught.

DISCUSSION

Few authors have reported fish predation on walleye eggs as a serious limiting factor. Goode (1912) mentions ". . . the destructive inroads of sturgeon, catfish and suckers on the spawning beds . . . " and ". . . not one-fourth of the eggs remain to be hatched." Small perch and minnows fed on walleye eggs and fry in a spawning stream near Constantia, New York (Bean 1912) but escapement of young walleyes was small. Suckers in Pike River, Minnesota were described as ". . . literally filled . . ." with walleye eggs and were believed to have ". . . cleaned up the spawning beds" (Surber 1925).

Predation by fish on walleye eggs at Kelleys Island Shoal in 1969–71 probably had little effect on the reproductive success of the walleye. It appears that only under uncommon conditions of an extended time interval between the spawning of perch and the hatching of walleye eggs and the presence of an unusually large population of perch, could egg predation by spent perch significantly reduce the reproductive success of walleye.

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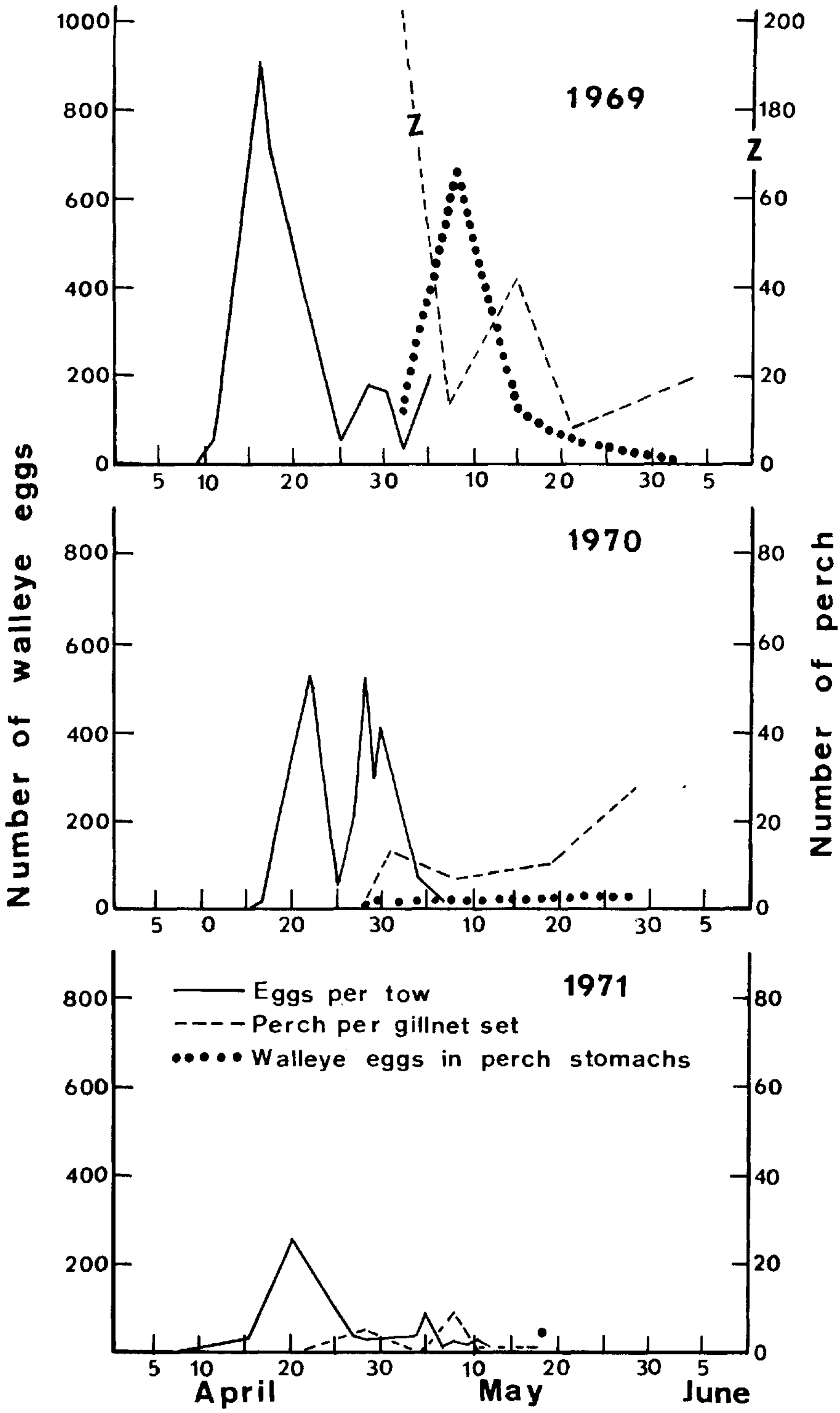
EXPLANATION OF FIGURE 3

FIGURE 3. Numbers of walleye eggs on Kelleys Island Shoal, mean numbers of eggs consumed by yellow perch, and relative numbers of perch on the reef at various dates during the walleye spawning and incubation period of 1969–71.



Number of walleye eggs
Number of perch
1969
1970
1971
1000
800
600
400
200
0
200
180
60
40
20
0
80
Z
Z
5
10
20
30
5
0
Eggs per tow
Perch per gillnet set
Walleye eggs in perch stomachs
April
May
June

FIGURE 3